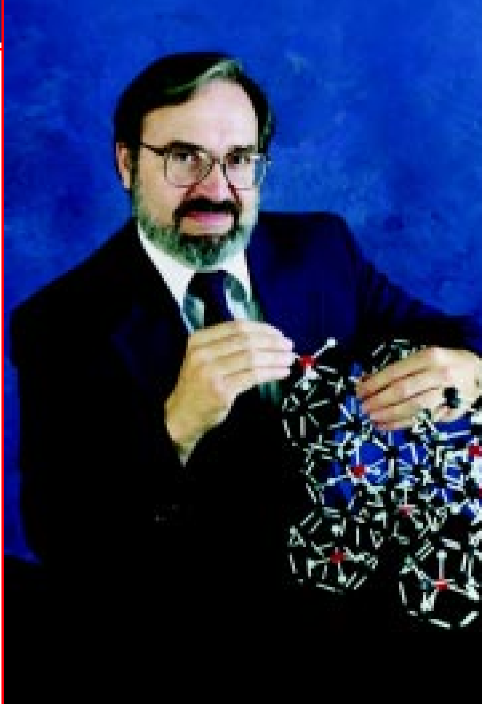

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Hydrates
Fire From Ice

If you touch a match to a sample of methane hydrates, the familiar gentle flames of burning natural gas appear, burning steadily as the ice slowly melts into a puddle. This “fire from ice” is by far the largest natural gas resource on Earth.

On a crisp, blue-sky March day in Canada’s Northwest Territories, the low-angle sun cast long shadows from Federal Energy Technology Center (FETC) scientist Thomas H. Mroz and other members of the international drilling team. As armed guards kept a vigil for uncongenial polar bears, the team turned their collars to the -10 °C wind. They waited as the drilling rig penetrated seven-tenths of a mile down through the thick Arctic permafrost. Scientists from a Japanese petroleum company (JAPEX), Woods Hole Oceanographic Institution, the U.S. Geological Survey (USGS), the Canadian Geological Survey, the Idaho National Engineering and Environmental Laboratory (INEEL), and FETC had teamed to sample an extraordinary substance that could provide a vast natural gas supply for the future: ***methane hydrates.***

Methane hydrates are ice-like solids that have methane gas frozen within them. The methane (the main component of natural gas) is

The methane hydrates test well was drilled on Richards Island in Canada’s Northwest Territories. Samples of hydrates were successfully recovered.

locked within a "cage" of ice. Few have actually seen methane hydrates, because they can exist only in cold temperatures and under high pressure. These conditions prevail in places that even scientists do not frequent: beneath the Arctic permafrost and below the seafloor. Bringing a sample of hydrates to the surface rapidly decomposes it, because the reduced pressure and warmer temperature allow the substance to melt, releasing its captive methane.

Far-sighted planners in government and industry know that conventional natural gas supplies are not likely to meet expanding demand, and new resources must be developed during the next two decades. The potential of hydrates has raised hopes of a vast new gas resource to exploit, and it is one of the hottest and coolest topics in energy research today. However, the true extent of the resource is unknown, and no technology exists for recovery of the methane. In the 1980s, FETC performed some of the earliest research on hydrates. Today, with new funding, FETC is leading the way once again.

Hydrates lie beneath the permafrost that covers thousands of square miles in Canada, Alaska, and Siberia. However, no human eyes had ever seen hydrates from beneath North America's surface, and very little data existed. So Mroz and the team traveled to the Canadian Far North, where several layers of methane hydrates had been inferred to exist in the frozen sediment beneath Richards Island. The inference came from logs of a test well drilled into the sands and gravels of the island, which is part of the Mackenzie River's icy delta where the river empties into the Arctic Ocean. The site is in caribou and polar bear country, at about 69° North latitude, some 3° above the Arctic Circle.

The test well, named Mallik L-38, was drilled by Imperial Oil in 1971. On the logs, petroleum scientists had spotted the telltale spikes of methane gas concentration and temperature shift that betrayed the presence of layers of hydrates—ten of them, totaling about 360 feet in thickness. They occurred between a quarter-mile and a half-mile below the surface.

(You can read more about the Mallik L-38 well. See the Geological Survey of Canada Homepage at sts.gsc.nrcan.gc.ca/page1/hydrate/hydrates.html)

New Methane Hydrates Test Well

The new test well was drilled only 100 feet from Mallik L-38 to make sure the layers of hydrates would have similar thicknesses and would be encountered at similar depths. The intent was to recover intact samples of the hydrates and to perform gas-production tests. The hope was that the frigid environment would keep the core samples frozen for study.

After several days of drilling and hauling up lengths of core, the diamond-toothed drill bit reached its target depth of over a mile below the surface. Logging instruments then were slowly drawn up the wellbore to sense methane gas, temperature, electrical, acoustic, and other parameters. Data from these instruments created a log of the sediment layers, from the bottom of the well up through the layers of hydrates to the permafrost.

Watching the videotape of the drill cores being opened, you can see the white, slushy hydrates mixed into the gravel, sand, and silt from the old river delta. The team collected samples of hydrates from the core and placed them in a dish of water, watching for telltale bubbles to rise through the water, the quickest way to detect the gas as it escapes from its icy bondage. One scientist picked up a small piece of hydrate and rolled it between his thumb and fingers. As it melted, it sputtered, fizzed, and bubbled as methane escaped into the air.

Recovered Cores are First North American Samples

Drilling of the methane hydrates test well can only be described as a struggle from start to finish. Scheduling and weather delays were followed by technical challenges and equipment problems. These were expected, as the team was testing new technology under harsh environmental conditions. This involved drilling a core a few inches in diameter through all ten hydrates layers and bringing them to the surface intact.

In the well, hydrates were encountered about a half-mile below the surface. Two stretches of core, representing layers of hydrates roughly 8 to 10 yards in vertical thickness, contained spectacular hydrates concentrations in porous sand and gravel. Each section released methane for several minutes after the cores were opened to the air. Opaque white hydrates were observed throughout several zones. Being able to witness this was remarkable, considering that the travel time to the surface was 2 to 3 hours, which is ample time for significant methane to escape the depressurized hydrates.

These samples are the first confirmed gas hydrates collected from beneath permafrost in North America. Because the goal of this research is to expand the natural gas supply, results from our research are extremely encouraging. In some samples, hydrates filled a significant part of the pore

It looks like plain ice, but it is loaded with natural gas that could fuel the future with help from FETC's technologies.

space that exists among the particles of sand and gravel. As tested in the laboratory, the maximum possible yield from pure hydrates is about 170 cubic centimeters of gas per gram of ice.

The team analyzed cores that contained permafrost and hydrates. Analysis of the cores and well logs suggests extremely high hydrates concentrations. Preliminary estimates from log data in the old Mallik L-38 well are that greater than 60-percent pore saturation occurs throughout most layers of hydrates, and in some cases nearly 100-percent saturation. Much research still lies ahead.

It is important to disseminate the data from this historic test. Team members are presenting results at an international symposium, and plans for further scientific studies are underway.

Hydrates History

Hydrates have been a laboratory curiosity since the nineteenth century. They also are a well-known problem in natural gas pipelines, where they form from moisture in the lines, creating costly icy clogs. But the vast store of hydrates beneath Earth's surface was not discovered until the 1960s, and was not considered a resource until recently.

This relative newness to scientists and the inaccessible locations of hydrates mean that the substance has been little-studied so far. However, the resource is generally accepted to be far greater than the conventional natural gas resources in sandstones and coal beds. Worldwide, proven natural gas reserves in conventional reservoirs are 5,000 trillion cubic feet (Tcf), but the hydrates resource may contain *hundreds of millions* of Tcf.

Hydrates are also extremely rich in methane. A cubic foot of hydrates, in the natural setting, can hold up to 170 cubic feet of gas. Hydrates can hold 40 to 100 times more methane than a cubic foot of the porous sandstone that forms a conventional gas reservoir. Far more gas can be recovered from a given volume of hydrates than from the same volume of conventional rock reservoir—potentially.

Furthermore, hydrates-cemented sediment creates a barrier that can trap free methane gas beneath them. This can create a "dual reservoir" of methane: the gas in the hydrates, plus the free methane beneath them. One strategy is to drill through the hydrates barrier into the free gas and harvest it while the diminishing pressure on the hydrates lets it break down to release more methane, recharging the reservoir.

Canadian sunset forms a backdrop for the Mallik 2L-38 test well north of the Arctic circle in the Northwest Territories.

Burning Dirty Sherbet

Depending on conditions, methane hydrates can resemble ice, or dirty sherbet, or frost. Hydrates are abundant not only in permafrost sediments of the Arctic, but are also widespread beneath the seafloor beyond the continental shelf, where water depth exceeds 1,000 feet. Both settings have the requisite methane source, moisture, low temperature, and high pressure needed to create methane hydrates. In sediment, hydrates act like cement to bind gravel, sand, and silt into layers that can become hundreds of feet thick.

FETC's Hydrates Research

Methane hydrates are nothing new to FETC. In 1982, FETC scientists analyzed a hydrates-bearing drill core from off the coast of Guatemala, recovered by the research vessel *Glomar Challenger*.

If technology can be developed to permit the economic production of natural gas from hydrates in great volumes, it could change the way the world uses fossil fuels. And this, of course, is why FETC is involved: as the U.S. government's première fossil-energy R&D facility, FETC is continuing to develop some of the technologies necessary to find, economically extract, transport, and use methane from hydrates.

Recognizing the promise of hydrates as a resource, DOE's budget for fiscal 1999 includes new funds for hydrates research. About $500,000 will fund FETC's mission to "establish a comprehensive interagency program to identify, characterize, and recover methane from the vast hydrates resources in both offshore and onshore (permafrost) regions." This interagency program includes FETC and the USGS (for hydrates geology), NOAA (National Oceanic and Atmospheric Administration, for ocean depth measurements), and the U.S. Naval Research Laboratory (for acoustic studies to help locate hydrates formations).

FETC researchers Rodney Malone and Bill Lawson ignite a sample of methane hydrates from a seafloor core recovered off the Guatemalan coast, part of FETC's early hydrates research conducted in the 1980s.

Once the best hydrates deposits are identified, the problems of recovering the methane and getting it to market are daunting. Releasing the methane from hydrates ice comes down to either depressurizing the substance or melting it. Trying to accomplish either beneath the seafloor or beneath permafrost will not be simple.

Developing the Hydrates Resource: Many Challenges

The USGS is estimating the methane hydrates resource of Alaska's North Slope. Of more than 400 Alaskan wells, 50 are inferred to contain hydrates, based on well logs. Many show multiple hydrates layers from 10 to 100 feet thick, as in the Mallik test well. The natural gas resource from Alaska's hydrates is estimated at over 600 Tcf (about 45 Tcf in discovered hydrates and 600 Tcf in undiscovered hydrates).

In addition to the vast Arctic hydrates formations, mapping off the South Carolina coast has disclosed large accumulations. Two areas the size of Rhode Island have very rich hydrates concentrations. The USGS estimates them to contain more than 1,300 Tcf of

Based on well logs, 50 Alaskan wells are inferred to contain hydrates.

methane (this is 70 times the entire U.S. natural gas consumption in 1989). Hydrates formations also exist off the coasts of Oregon, California, New Jersey, Alaska, the Gulf Coast states, India, Japan, Norway, and other locations.

With this wealth off our shores and in the Arctic, we must consider what it will take to commercially develop methane hydrates. How can we access hydrates that are buried under Arctic permafrost or lie beneath 1,000 feet or more of ocean? How can we extract the methane frozen in the hydrates? How can we transport the methane from such remote sites to where it is needed, thousands of miles away—pipeline it as a gas, or liquefy it first? How pure is the methane from hydrates? How reliable could the supply be? How often will we have to move the extraction equipment from a depleted site to an untapped one? And, underscoring all of these questions: what is the cost? Is methane recovery from hydrates economically feasible, or is this just an ice dream?

The Future

Methane hydrates have the potential to become a major natural gas source. The resource may also be a major player in global climate change. But our knowledge of hydrates is in its infancy, and new knowledge must be built on the work done so far by FETC, the USGS, and others. It is likely that the next generation not only will know all about methane hydrates, but may also heat their homes with its rich load of fossil energy. In the meantime, Earth is keeping its vast store of hydrates on ice.

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